THE PROBLEM

OF THE

MISSISSIPPI.

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INTRODUCTORY.

It has been said that "Egypt is the Nile and the Nile is Egypt," so closely identified is the great river with the great nation which for many centuries dominated the kingdoms of the world and diffused the light of its civilization even to present generations.

This granary of the Continents owed its productivity, wealth, power, influence and population to the annual *inundations* of the Nile which deposited a fertile silt beyond its borders and irrigated its extensive rice and pasture lands. This beneficent provision of nature which was so extensively applied in the days of the Pharaohs, and of Joseph, is still recognized by the foreigners in that country, whose energies are directed to increase the productivity still more by the construction of Lake Moeris and the maintenance of the irrigation dams and canals of the Damietta and Rosetta Branches of the Delta.

In strong contrast with this foreign policy of enrichment by overflow and irrigation our own engineers appear to be wedded to a system of exclusion and drainage by levees designed to confine the waters of the uplands so richly charged with alluvion, to the narrow bed of the stream and to attempt the impossible problem of compelling the currents with their ever diminishing velocity, due to reduction of slope, from head to mouth, to convey *all* the detritus of the region to the Gulf of Mexico.

The following data are collated from the best authorities and are submitted, not in a spirit of criticism but as logical deductions from historic facts and observations which carry with them the force of conviction to unprejudiced minds. The logical conclusions to which these data lead are of such momentous importance as to justify the careful personal consideration of all classes of our citizens, in order that great calamities may be averted in the future.

The destruction of the great reservoir Naharaga, and its dependent irrigation system, by Cyrus, converted the fertile plains of Mesopotamia into an uninhabitable wilderness. Let us take warnings from the past and "wisely improve the present," that we may safeguard the future of this great Republic.

The Problem of the Mississippi.

BY

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IMPORTANT FACTS FROM OFFICIAL AND OTHER SOURCES:

The tide water of the Gulf of Mexico formerly extended to the mouth of the Ohio river, the whole country below Cairo being an alluvial deposit.

These alluvial deposits have raised the level of the land at Cairo, and, as a consequence, the bed of the stream also more than 300 feet. This statement has been both affirmed and denied, but it is certain that the alluvial deposits at and near Cairo are of great depths.

Until recent years, the overflows from the river in a state of nature have been chiefly deposited in immense basins, aggregating nearly 30,000 square miles, and, as the heavier particles, are first deposited, ridges have been formed on each bank at times reaching 15 feet higher than the bottom-lands more remote from the channel.

The sediment not deposited in the basins is carried by the stream; dropping upon the bed the heavier particles, whenever the velocity is reduced, and carrying the lighter particles to the Gulf.

The sediment carried to the Gulf is so light that it is said several days are required before a portion enclosed in a glass jar will settle to the bottom, and yet the quantity is so enormous that a flood, if carrying 2,000,000 cubic feet per second, would in 24 hours, if !! discharged in the Gulf, cover 4050 acres to a depth of one foot and in 60 years the fill 10 miles out from the passes is said to have been 620 feet and that the surface will be reached in about 15 years more.

It has been estimated that with all the tributaries in full flood at the same time as the main river the total discharge of water might reach 3,000,000 cubic feet per second.

2,000,000 cubic feet per second is considered a conservative estimate of the discharge during a high flocd.

Of this volume only one half, or 1,000,000 cubic feet per second reaches the Gulf at the mouth of the river.

The balance is carried off by lateral streams, held back in the basins, dissipated by evaporations, or retained by absorption.

The overflow into the St. Francis Basin is estimated at 300,000 cubic feet per second or more.

The St. Francis Basin is 190 miles long and 35 miles wide.

This overflow consumed 17 days in 1890 and 23 days in 1891 in reaching Helena, usually about 2 weeks.

William Starling estimated that the closure of the St. Francis and White River Basins would raise the crest of the flood at Helena 5 feet.

The same writer stated that the gauge at Sunflower would undoubtedly have stood 7 feet, or more, above all previous records if crevasses had not occured in the levees in front of the White River Basin and the levees would have been deeply submerged if something had not given away.

This result followed the practical closing of the basins by levees. A gap of 100 miles still remains open in the St. Francis Basin.

Every reduction of velocity in a silt-bearing stream causes deposits and the velocity is dependent upon the slope. The fall of the stream is 5 inches to the mile from Cairo to Memphis–velocity 5 miles per hour; 4 inches from Memphis to Vicksburg–velocity 4 miles per hour; 3½ inches from Vicksburg to Red River; 2 inches from the mouth of Red River to New Orleans and 1 inch from New Orleans to the Gulf. The velocity varies with the slope, from 5 miles per hour above Memphis to one mile per hour below New Orleans.

It has been stated that a crevasse at Bonnet Carre, a short distance above New Orleans, which discharged one-twelfth of the flood water through Lake Pontchartrain, in going 6 miles instead of 160 miles to the River's mouth, lowered the high water mark at New Orleans from 3 to 4 feet where the rise and fall was 17 feet, and lowered it at Natchez, 300 miles above, from 6 to 8 feet where the rise and fall was 50 feet.

It is also claimed that an outlet one mile wide by 10 by 12 feet deep with a fall of 12 feet in going 6 miles to Lake Borgne, would divert one-twelfth more of the discharge and reduce the high water level at New Orleans in all 8 or 10 feet and at Natchez from 14 to 15 feet.

NOTES FROM WILLIAM STARLING 1897:

The rivers emptying into the Mississippi cannot be leveed, as the valleys cannot be drained by pumping. The rain water discharge at the mouth of the Yazoo river reaches 100,000 cubic feet per second, which is 60 to 70 times the capacity of the greatest pumping plant in existence.

In May 1892 the discharge which passed St. Louis was 74 p. ct. of that passing Cairo and in 1858 about the same proportion.

The Missouri contributes two-thirds ot the solid matter brought to the Mississippi.

A part of the flood discharge of the Red River passes off through the Atchafalaya.

Like the St. Francis reservoir, the upper part of the White River basins, before it was closed, acted as a waste-weir for the surplus water of the river, reducing the height of the water very materially, perhaps 2 or 3 feet.

The closure of the St. Francis and White River basins will probably raise the crest of the wave at Helena 5 feet.

The closure of the upper basins will have the undesirable effect of bringing the floods from the upper rivers into closer coincidence with those of the White and Arkansas and this may justly be considered a serious element of danger.

In 1892 the outpour of the Arkansas was more than half that of the Missouri in full flood, but two-thirds never reached the Mississippi at all, but went around the head of the Tensas system of levees, which *was then open.*

The flood of 1897 is important to the engineer from the wholesale closure of unleveed tracts and the extraordinary elevation of its high water consequent thereon.

The St. Francis basin was closed since 1893 to a distance measured along the river of 120 miles and a gap of 100 miles still remains. The White River Basin has been closed. It is to the building of these lines and the maintenance of the lines previously existing that the unparalleled stages attained by the water have been due.

INCREASING ELEVATION OF FLOODS IN THE LOWER MISSISSIPPI RIVER.

Extract from paper read by L. W. Brown, C. E., before the Louisiana Engineering Society, March 11, 1891.

This is the most recent and in many respects the most able and reliable paper ever presented to the Engineering Profession on this subject, with the possible exception of the recent paper of James A. Sedden, hereinafter quoted.

The paper is the result of 21 years observation by the writer, during 15 years of which he was directly connected, officially and otherwise, with the levee work. The paper should be studied carefully; a few extracts only can here be given.

Twenty years ago the levees were of very small dimensions and very low in elevation as compared with those now existing. The levees in the third district were but little larger than a well-banked potato row.

In a very few decades the construction of levees to properly secure us against inundation will become a prodigious undertaking, both as an engineering feat and as a revenue consumer.

Why should the maximum floods increase in elevation when a corresponding increase of discharge is not apparent ? Why did the normal flood of 1898, discharging very considerable less volume than the great floods of 1851 and 1890, acquire greater flood elevation ?

February 26, 1890 flood volume 1,422,000 cubic feet per second. Height 14.7 ft.

May 2, 1898, flood volume 1,084,000 cubic feet per second. Height 16.65 ft.

or a flood 30 p. ct. less in volume gave 2 feet greater height in an interval of 8 years.

The flood elevation of 1874 was not surpassed until 1890. In 1897 the maximum elevation was 3.47 feet higher than the extraordinary flood of 1874 twenty-three years previous.

While the difference in elevation of the flood of 1897 above the sea level was 22 per cent. more than that of 1874, the discharge was only 12 per cent. greater.

The records show that the discharge for latter years is much less than in former years for same elevation of flood. Referring to a list given of great floods, it is found that from 1828 to 1874, a period of 46 years, the increase in the height of the floods was only at the rate of one foot in 90 years, while the flood of 1897 was 3.74 feet higher than the flood of 1874 or at the rate of one foot in 6½ years. The flood of 1890 was 3.07 feet below that of 1897 or at the rate of a foot in 2½ years.

The facts presented would indicate a future rate of increase of the height of floods of one foot in 5 years and this increase will probably be exceeded. Hence the levees of 1950 will be 10 feet higher than at present, under which conditions the whole delta will be confiscated for levee protection and commerce on the lower Mississippi will be rendered wholly impracticable.

Charles Ellett, who represented the U. S. Government in connection with river investigation in 1851, was sufficiently bold to assert that to sustain a flood of the intensity of that of 1851 the levees must be made at least 2 feet higher from Red River to New Orleans, for which assertion he was in 1861 severely criticised by the representatives of the Government in charge of river matters.

The prophecy of Mr. Ellett has been more than realized. Instead of 2 feet, levees are now 5 feet higher than in 1851.

The estimate of the Government Engineers in 1861 for complete protection from Cairo to the Gulf, including value of existing levees, was $26,000,000. There have been expended since 1861 in levees still incomplete more than $50,000,000, and the cost of the levee system when completed will not be less than $100,000,000, if built at once, but more, if built gradually.

When the levee system was inaugurated, between the years 1860 and 1880, no marked increase in the elevation of floods was apparent. The records show an increase of only nine-tenths of a foot from 1828 to

1890, a period of 62 years, while from 1890 to 1897 the records show an increase of 3.07 feet in seven years.

The advocates of the all levee system have persistently condemned all suggestions which would reduce the elevation of floods, even when made by prominent, accomplished, brilliant, and learned members of the civil engineering profession.

The careful consideration of the records of great floods for the past seventy years would clearly indicate that the volume is not increasing, and there is every reason why the maximum volume should not increase with the settling up and improvement of the country.

Mr. Brown gives an estimate of the amount of deposits in the Gulf based on a discharge of 400,000 cubic feet per second for 120 days in the year and solid matter, one part in 1500 filling 250,000 acres to a depth of 5 inches equivalent to 102,400,000 cubic yards.

In a second paper read before the Louisiana Engineering Society on May 8, 1901, the slopes are given on several stretches of the Lower Mississippi for 10 seasons, covering the past 30 years, which demonstrate that the theory on which the improvements of the Mississippi river are now being made, is wholly and radically wrong.

After the reading of the paper by Mr. Brown at the meeting of the Louisiana Engineering Society a discussion ensued which was participated in by Messrs. H. B. Richardson and B. M. Harrod in defence of the plans of the Mississippi River Commission.

In his reply Mr. Brown stated that Majors Richardson and Harrod had in their discussion studiously avoided any reference to the fact that the levees are enormously higher today than two decades ago and the levees in 1897 were only by great exertions made to answer their purpose. He then proceeded to establish by the writings, theories and actions of the Mississippi River

Commission, that the slope is decreased in proportion as the height of floods has been increased by their own works.

A maxim is laid down that to improve the flow or discharge of any stream we must improve the outlet and thus increase the slope.

Mr. Brown asks: "Has the Mississippi River Commission such knowledge and has it made such investigations as are necessary to determine that the bed of the river is not being elevated ? If they have, why is not this most valuable information made public ? If the flood elevations are increased, as past experience teaches us they have been, and if they have occasioned a decrease in the slope of the whole river, as is shown to be the case, although not published by the Commission, by what hydraulic laws would the deduction be made that the bed is not fouling ? If no phenomenon has occured which was not anticipated by them, the Commission is responsible for the losses this country sustained in 1897 amounting to upwards of $100,000,000, by not adopting in 1894 a grade for levees 4 feet above the high water of 1897 instead of adopting this tremendous elevation in 1898 and with the same reasoning the Commission should at once give us the proper elevation for 1905 so that we can construct them economically.

Other statistics are given showing that the predictions of the engineers in regard to the proper height of levees for protection have been unfulfilled.

NOTES FROM PAPER OF CAPT. JOHN COWDON, 1897, FROM NEW ORLEANS ITEM, APRIL 13th, 1897.

The Northern shore of the Gulf of Mexico was at one time 40 miles above Cairo.

The river has all the time been raising its bed, banks and high and low water lines.

Logs have been found by borings from 100 to 300 feet under the surface from Cairo to New Orleans.

Current from Humphrey's report, 5 miles per hour at Cairo. 4 miles per hour Memphis to Vicksburg, reducing gradually to slack water near the Gulf.

The flood of 1858 gave 1,675,000 cubic feet per second at Cairo with additions from other tributaries to make 2,000,000 cubic feet per second: at the same flood the outflow passing New Orleans was only 1,100,000 cu. feet per second. The Mississippi River Commission stated that in 1890 the inflow at Cairo and down to Red River was 2,200,000 cu. ft. per second and the discharge by New Orleans 1,000,000 cubic feet per second.

A number of points are named on pages 3, 4, 5 and 6 Senate Document No. 125, 55th Congress, 1st session, at which outlets could be made for the relief of the flood water.

The charge is made that in order to convey the impression that recent flood has not been higher than predecessor, the gauge marks set by General Humphrey in 1854 have been raised 2 feet at Carrollton and still higher at other points.

The Mississippi River has shoaled to 5½ feet at a dozen places below Cairo.

No matter how arduously all elements, cities, counties, states, and the nation may co-operate to build a system of levees high enough to be out of reach of the highest water of record, the mighty river will fill its confined bed with silt and the levees will have to be elevated correspondingly, only to give way finally before the next great flood.

Referring to the flood of 1897, the New Orleans "States" of April 18th declares that, but for the invaluble relief of the Atchafalaya outlet, this Metropolis of the South would already have been doomed to present devastation and future decay. The Atchafalaya so far has been the means of saving this city and the rich riparian country below the Red River from overflow and all the horrors that such a fate means.

In 1871 and again in 1874 New Orleans was saved from destruction by crevasse at Bonnet Carre, in 1884 by the breaking of the Davis levee and in 1890 the torrent passed over the levees at New Orleans and ran down Canal Street hub deep to the vehicles thereon, but again the city was saved by the breaking of the Nita crevasse. The same history of danger and relief was written up in 1893 in the Belmont and Sarpy crevasses.

Capt. King of the U. S. Engineers stated before a Congressional Committee that but for the break at the Nita Crevasse, the water at New Orleans would have been two feet higher. The flood was already passing over the levees when the break occured.

At Lake Borgne the flood water of the Mississippi could get to the Gulf in 6 miles with a fall of 15 feet rather than run to the present outlets at the mouths of the river for 116 miles with the same fall.

Gauge reading shown to be incorrect. Smoke pipes knocked off steamboat in consequence of water being higher than the gauge reading indicated. The owner of the boat sought to recover damages but had no recourse, as the Goyernment was the party at fault.

Some engineers are suggesting and planning a Bohemia levee district to extend down to Fort St. Philip, a distance of 25 miles. If they succeed in securing the means and build levees high and strong enough to resist future floods, New Orleans and the country above will have to build higher and stronger levees, for the checked flood, unable to get out of the mouth, will regurgitate over all levees of present grade.

So the fight will go on until some such catastrophe as occured in China, when the Yellow River levees broke and drowned 3,000,000 people. The levees at or near the discharging point of the Mississippi will be built higher and stronger, and those above will break, and they in turn will be built higher when the flood has gone, only to result in the destruction of those below.

Extracts from statements of J. A. Ockerson, Civil Engineer and Member of the Mississippi River Commission, from "Riparian Lands of the Mississippi."

"Below Gray's Point the normal condition of the stream is often affected by back water from the Ohio which causes a deposit of sediment that becomes a prolific source of annoyance to navigation."

In the fourth reach from the mouth of the Ohio to Red River the bed of the stream is through deposits which it has built up and torn down repeatedly.

Continuous levee advocates claim that there are no deposits upon the bed and that, on the contrary, there is a scour which deepens the channel and lowers the flood plane.

The erosion of the banks by the current amounts to an average area of about 9 acres per annum for each mile of river.

Only a minute portion of the material can be carried to the Gulf, because of reduced velocity and slope. Where can it be deposited if not in the river ?

NOTES FROM REPORT OF MESSRS. HUMPHREY & ABBOTT IN 1861.

"The popular idea that a slight artificial retardation of the current such as that caused by a crevasse must produce a deposit in the channel of the river below it is proved to be an error. No artificial diminution of the high water of the river can produce a deposit in the channel."

"In 1851 the amount of sediment carried by the Mississippi was maximum one part in 681 average one in 1808. In 1852 maximum one in 572 average one in 1449.

The ratio between surface and true mean velocity is 1x1.2.

"Besides the amount held in suspension, the Mississippi pushes along into the Gulf large quantities of earthy matter.

It appears to be about 750,000,000 cubic feet which would cover a square mile 27 feet deep.

The total yearly contribution from the river to the Gulf amounts to a prism 208 feet in height with a base of one square mile equal to 278,000,000 cubic yards.

The following table gives the maximum discharge per second in cubic feet in the great flood of 1858, the duration of the flood above the banks in days and the height to which the elevation of the flood would have been increased if the continuous levee system had been completed at that time, as estimated by Messrs. Humphrey and Abbott.

Station.	Discharge.	Duration.	Increase.
Columbus	1,478,000	24	1.8
Memphis	1,380,000	87	6.5
Helena	"	"	3.9
Napoleon	1,369,000	100	6.9
Lake Providence	1,418,000	—	9.8
Vicksburg	1,406,000	129	3.8
Natchez	1,430,000	129	4.6
Red River Landing	1,338,000	118	3.2
Baton Rouge	1,338,000		2.7
Donaldsonville	1,297,000	129	2.2
Carrollton	1,297,000	199	2.4

If the proposed levees to secure absolute protection were supposed to be entirely new, the estimate was $25,932,000 and to bring the existing levees up to this standard the amount thus to be expended was estimated at that time, 1862, to be $17,000,000. Experience has now shown that an expenditure five times as great as this estimate would not have secured the protection so confidently anticipated.

PROPOSED OUTLET AT BONNET CARRE.

There can be no doubt that by making two levees from the river to the lake and cutting the Mississippi levee between them, a high water outlet of any dimension can be made. Such an outlet would be of utility in reducing the height of *floods* for many miles above and below.

LAKE BORGNE OUTLET.

If outlets are to be used, this is the locality for their trial, since the results would be less injurious here than at Lake Pontchartrain.

To reduce the maximum discharge of the flood of 1858 to that of 1851 would require the abstraction from the river of 150,000 cubic feet per second.

This would raise the surface of Lake Pontchartrain 2 feet and would flood the rear of the plantations, which are but one or two feet above the lake. Levees must therefore be built along the edge of the swamp.

STATEMENT OF JAMES A. SEDDON.

Paper read before the Western Society of Engineers, discussed by Messrs. Lyman E. Cooley, Robert E. McMath, C. H. Tutton, Isham Randolph, Thomas T. Johnson and James A. Seddon. The report states that "The discussions of Messrs. Randolph, McMath, Johnston and Tutton practically express unqualified approval of the main propositions."

EXTRACTS.

In river problems, each case is to be settled only in a special study of its data.

All along the basins the ground slopes back from the Mississippi into an area of low swamps threaded with lakes and bayous which act as a system of great reservoirs, which retain the flood excesses.

The larger basin lying between Cairo and Helena known as the St. Francis is the only one now remaining partly open. The line as first built was much too low to withstand the increased flood height that followed the restricted overflow and the great flood of 1897, the first that had come against it, broke through the levee in a number of places before it had reached its extreme by several feet. But it nevertheless gave the last and the best indication of what flood heights may be expected when the overflow into this natural reservoir system is entirely closed out.

The spill over the banks into the swamp basin begins at a discharge level of 1,000,000 cubic feet per second which is 12 feet below the extreme stage of the flood at Cairo. The discharge level of 1,700,000 cubic feet per second at Cairo is cut down by the overflow, to a 1,200,000 cu. ft. discharge at Memphis.

The paper of Mr. Seddon is illustrated by numerous flood hydrographs showing the extent to which the extreme height of the floods would be planed off, if portions of the volume could be withdrawn in the upper reaches and the marked effect of a system of swamp reservoirs upon the floods strikes the eye upon the first glance at it. From January first, the beginning of overflow, to the latter part of July, when the river again gets within banks, all the flood extremes at Cairo are planed off by the outflow, and all the lower stages between these extremes filled with it. The basins cannot hold the floodwater back for the low water period. From ten days to two weeks is about the retardation of each of them and in a flood period of months, it must practically all come out again on it. But even where it comes out, this reservoir system has considerably cut down the extremes in its levelling up process, while at such points of maximum outflow as Memphis and Lake Providence it has about relieved the Mississippi of one-third of its flow and a great river of some 500,000 discharge is carried down in the swamps outside of it.

In contrast to the free overflow in 1882, the flood of 1897 subject to the levee restraints is most striking. With an isolated flood at Cairo some 0.3 feet lower, from Helena down the extreme high water stage is raised from 4 to 6 feet and this notwithstanding the fact that a good part of the St. Francis basin remained open while the levee that was there gave way when the river was still some 200,000 to 300,000 below its maximum discharge. From there down the flood in succession, notwithstanding its reduced volume, broke through the Yazoo, White and Tensas levee systems in a number of places.

Altogether then, from the evidence of this 1897 flood, there is little doubt that to shut off the outflow completely from all these great basins, is to raise the high water stage of such floods from 6 to 8 feet above the levels at which the natural reservoir system of the river would have carried them and even in the interest of a real flood protection alone, it would certainly be wise to consider whether some less dangerous step into the unknown might not be substituted for it.

Had the St. Francis basin in 1882 simply been cross-leveed at intervals, with outlets under control, making of it a chain of reservoirs to hold the flood water, there would then have been no return flow at Helena, no corresponding outflow into the Yazoo, no inflow crest at Vicksburg, and while there would still have been some overflow, yet from Memphis down there would have been no great flood that year, certainly nothing that a very moderate levee system could not safely have carried.

Considering the increasing risk that each additional foot to the high water stages throws upon all the land behind the levees along the whole valley, there is very little doubt that, holding the flood waters back, once for all, at the head of the system and never having extreme floods, is true flood protection, even if it does sacrifice some 13 per cent. of swamp area.

As one of the most serious problems of the Lower Mississippi, the erosion of a river that rises and falls some 50 feet against banks of light alluvium, the bed changes in this case are most threatening.

Indeed, the matter of caving banks on the Lower Mississippi is only second in importance to the flood protection, and in fact the two are closely related. In long reaches the bank erosion has its annual average of some 125 feet, that year by year eats its way into the levee line and a new line has to be constructed back of it, and not only has the river a sure mortgage on the land adjoining it, but there are few of the towns and cities along its course that have not a more or less continual fight with this movement of the river to hold their wharfage and front properties, in which the river finally conquers.

With the reservoir system in the St. Francis basin a wholly new regime would begin at Helena. With some 10 feet cut off the top of all floods there, and 100,000 cubic feet per second for two hundred days put back on the short low water period of the river, the range from high to low water, even in extreme floods, would be little more than 25 feet, while the ordinary rise and fall would be near 15, in contrast with the condition of a complete levee restraint, with its ordinary range sometimes over 40 feet and an extreme range of over 50 feet.

With the reservoirs in the St. Francis basin, the levee system already completed below the White and Arkansas Rivers would certainly be enough for any possible contingency, while there are possible contingencies in the combination of these lower floods, with a complete restraint from above that no levee system yet considered would begin to stand against.

Mr. Seddon concludes his paper with this paragraph:

Finally it may be noted that in the last 20 years the Government has spent on this river some $40,000,000, or just about the cost of the St. Francis reservoir system with slack water navigation (20 feet depth) to Cairo. That it has spent the most of this to pay for experience is now generally admitted and it may be admitted that perhaps it could not have gotten this experience any cheaper. But in any event, if the matter was worth beginning, it is certainly now worth finishing with such a waterway in sight, carrying, as it does, this high degree of flood and bank protection with it. The final question then is simply.—Having paid $40,000,000 here for experience, does the country now propose to profit by it ?

DISCUSSION.

The advocates of levees claim that by confining the river by continuous levees on both sides the velocity will be increased, a scour produced, the cross-section enlarged and a more rapid flood discharge induced.

There is nothing to justify this opinion. Velocity depends upon slope and as the length has been increasing by deposits in the Gulf while the total fall to mean tide level remains constant, the mean average slope must be diminished, but cannot be increased. The idea of a general secur of the whole bed is an absurdity.

Where there are contractions below the mean average cross section, there may be scours, but they are local. The contraction acts as a dam, causes congestion with a rise of elevation for an indefinite distance above the contracted point and an increase of slope below, but any increase of slope at one point is compensated by a reduction when the area below becomes enlarged and if any material is removed, it is soon re-deposited and cannot be carried to the Gulf by local expansion and contraction, with diminishing and alternating velocities due to slope.

The variations in slope are from 5 inches to a mile near Cairo to one inch to a mile near New Orleans, with corresponding variations of velocity. The heaviest particles of silt are deposited in the upper valley on the bed and in the bottoms. The very lightest particles only are carried to the Gulf, yet the quantity is so enormous that writers have stated that the Gulf has filled to a depth of 620 feet and to a distance of 10 miles from the mouth and the bed has been raised at Cairo over 300 feet; yet it is apparently contended by the levee advocates that there are no longer any deposits on the bed and the bed cannot rise. Those who support this contention must indicate the time when the streams ceased to carry silt and make deposits and when the bed ceased to rise, and must prove that the silt carried to the Gulf is equal in quantity to that brought to the river by the tributaries.

It has been shown that before the river was interfered with by the construction of continuous levees, the changes in flood elevations were very slow, only one foot in 90 years, while the construction of levees has caused a rise as great as one foot in 2½ years.

The St. Francis basin contains over 6000 square miles. 300,000 cubic feet per second pours into it from the overflow in high floods. Spreading over this immense area the velocity is very slow, requiring sometimes three weeks to reach Helena; during this slow progress the sediments must be nearly all deposited on the flats and only clear, or nearly clear water discharged into the river. When the St. Francis basin shall have been closed entirely, what will become of this sediment ? As it consists of the heaviest particles and those soonest deposited, the quantity may be ten times as great as is the portion carried to the Gulf. Will it be deposited at the mouth ? If so, the slack water of the lower river must have the transporting power of the swiftest current at the upper end. If not deposited in the Gulf, can the most fertile imagination conceive any other place of deposit than on the bed of the stream ? The St. Francis basin contains 6706 square miles and if the width of the Mississippi be taken at 4000 feet, one inch of deposit over the basin of the St. Francis alone would fill the bed of the Mississippi to a height of 5.7 feet for a distance of 100 miles. But the St. Francis is only one of the several basins aggregating 29,790 square miles, the deposits from all of which must be thrown into the river when the levee system shall have been complete. Can there be a greater absurdity than to assume that with double the quantity of water thrown into the river and all the basins closed, there will be no increase required in the height of the levees and that a system that has caused an increased height of flood with a reduced volume of water and with openings remaining of considerable magnitude, can afford efficient protection when the safety valves are all closed and the volume of discharge doubled?

In 1879 Col. Suter found the mean proportion of water to sediment near the mouth of the Missouri to be 265 to 1. As the outpour into the St. Francis is at the upper end where the water is largely charged with sediment, it may be fair to take 500 to 1 as a basis of calculation.

Mr. Brown estimated the annual discharge into the Gulf as equivalent to 400,000 cubic feet per second for 120 days, which is more than one third of the normal discharge in floods at the mouth of the river. If as an approximate calculation, we take one-third of the flood discharge into the St. Francis or 100,000 cubic feet per second for 120 days, carrying one five-hundredth part of the sediment, there would be sufficient to make an annual deposit on the bed of the Mississippi 100 miles in length and one inch and two tenths in depth. Of course, there are no data for accurate calculations of this nature, but even a light annual deposit continued for years will soon have a perceptible influence on flood elevation. The South Pass has been filling up at the rate of nearly five inches per year.

This matter of deposits, consequent upon the construction of continuous levees, has not received the consideration to which its importance entitles it. The rise of the bed by deposits has been too slow heretofore to attract much attention and it has not been continuous, but upon the completion of the levee system the amount of deposits will be vastly increased and will be augmented by all the former deposits in the basins.

When the levee system shall have been completed, if folly shall be permitted to extend so far, it will then become necessary to make openings in the levees to afford relief; but even that will not remove the deposits upon the bed and restore the river to its normal condition.

The Panama Canal Company has been able by the use of steam shovels and the best appliances known at the time, to remove one million cubic yards per year. The deposits at the mouth of the Mississippi are now over two hundred million cubic yards per annum. They must be increased largely when the levees are completed. How is a navigable channel to New Orleans to be kept open ? If the course of the river, in accord with the universal plans of the Government engineers, should be extended by means of twin jetties, these jetties will form an obstruction, increase the congestion and the height of floods, and as the velocity of discharge will be feeble, it will be impossible to provide dredging plant sufficient to keep an open channel, as a large amount of the transported sediment must be dropped between, above or beyond the jetties, how much no man living can calculate.

The maintenance of a channel through the deposits in the Gulf will not be the only difficulty. The congestion caused by the Eads jetties in the South Pass has caused the river above to fill with sediment in places to a height of 55 feet, so that dredging is even now required to keep the present channel open to New Orleans, and the congestion at the mouth has increased the height of the flood planes above.

The twin jetty plan of harbor improvement is unsound in theory, difficult of adjustment to a varying regimen and has almost universally proven a failure in practice, compelling a resort to dredging to create and maintain a navigable channel.

No single plan of improvement can solve the problem of the Mississippi,—neither levees, outlets, waste wiers or diversions will singly be sufficient, but a combination of all, directed by intelligence. Levees are required for local protection, but a system of continuous levees for highest floods from Cairo to the Gulf is the worst that could have been conceived.

If as Engineer Brown has stated, a flood discharging 30 p, ct. less water than a preceding one raised the height of the water two feet in consequence of the closure of the outlets only in part; what will be the rise where the volume of water shall be doubled and all the outlets entirely closed ?

THE REMEDY.

To provide early relief it would therefore become necessary to remove portions of the levees already constructed. The outlets will demand immediate and careful consideration. The reports of Humphreys and Abbott admitted that outlets would reduce very greatly the height of the floods but condemned them on the ground that they would become so enlarged as to divert too much of the water, impair low water navigation and flood the districts in their vicinity, causing great loss of property.

These objections are purely chimerical. It would be a very simple engineering problem to construct the outlets of such material of such height from the bottom and of such width that there could be no enlargement. If the sills should be at proper height, the low water navigation would not be affected, and if wide enough, only the high waters would be deflected and the low grounds through which they passed could be easily protected by low levees of inconsiderable height as compared with those required for protection on the main river.

The outlets required below and near New Orleans would relieve all danger from floods: but there will be required levees for local protection and the questions of water wiers or spill ways, local reservoirs, for retention of flood water and for irrigation and other less important questions would, of course, receive attention, and an intelligent, practical and useful settlement could then be confidently expected and the great problem of the Mississippi would be solved, the overflow would cease, confidence be restored, life and property saved and an era of prosperity inaugurated which never can be attained under a system in reference to which an eminent Senator, after a hearing of representatives of Civil Engineering Societies, declared that if a worse system could be found anywhere else on Earth he would like to know where to look for it.

MEASURES REQUIRED TO INSURE COMPLETE AND PERMANENT PROTECTION.

Open outlets without delay as the quickest and most efficient mode of protection. The objections to them are futile. It has been clearly shown by Messrs. Humphreys and Abbott that outlets do not cause deposits in the stream to interfere with navigation, and the outlets can be so constructed that there can be no danger of enlargement. The sills can be of permanent construction and the elevation such that they will take off the crest of the flood waves and cease to act as spill ways when the water falls to an ordinary boating stage.

The Lake Borgne outlet should be the first to be utilized, but the others should be opened also either simultaneously or successively, the principal of which would be at the Atchafalaya and at Lake Pontchartrain. While admitting that outlets would reduce the height of the floods for long distances, Messrs. Humphreys and Abbott in their voluminous report condemned the proposed outlet via Lake Pontchartrain, on the ground that outlets would enlarge and carry off too large a portion of the water of the stream, thus endangering navigation; also that the Lake would be filled up with sediment, the waters raised probably 2 feet, and the plantations, some of which were only 2 feet higher than the Lake, might be damaged by overflow in case of storms. These objections seem to be purely chimerical. If any protection should be needed to the plantations on the borders of Lake Pontchartrain, levees two feet high would be amply sufficient, the construction of which would involve an expense absolutely insignificant in comparison with the Mississippi levees of great height extending for thousands of miles from the Gulf to Cairo.

Six times at least has New Orleans been saved from destruction only by the fortunate occurence of the breaking of levees which caused crevasses or outlets, and quickly depressed the flood level below the danger point. With higher levees the danger will be increased, but with permanent outlets properly located and constructed and an abandonment of all work on the continuous levees, all future danger can be averted. Mr. L. W. Brown, in his valuable paper previously referred to has shown clearly that outlets are absolutely necessary for the safety of the Lower Mississippi Valley and the protection of life and property and their construction should be no longer delayed.

The plan proposed by James A. Seddon for the construction of a series of reservoirs in the St. Francis Basin is worthy of the most careful consideration. This plan has been approved by eminent Civil Engineers. It was stated that the flood of 1897 was 0.3 feet lower at Cairo than the flood of 1882 and yet in consequence of the partial closing of the St. Francis Basin by levees, the crest of the flood at Helena was raised from 4 to 6 feet.

The effect of the reservoirs would be to reduce the crest of the flood waves several feet all the way to the Gulf and leave the lower country free from overflow by crevasses, but other and very important results would also flow from such construction. A large area of productive land could be irrigated while the reservoirs would be chiefly located upon the lowest swamps, which are irreclaimable.

In addition, the outflow from the reservoirs would for a long time help to maintain the river in a navigable stage, and by means of locks at the lower ends of the reservoirs Mr. Seddon claims that a slack water navigation could be secured with a depth of 20 feet all the way from the Gulf to Cairo, there to connect with the Drainage Canal to Chicago and in time establish a line of interior water communications with a navigable depth of 20 feet from New York to New Orleans, the effect of which upon the development of the country and the prosperity of the nation the wildest imagination could scarcely be able to exaggerate.

The question as to whether the proposed system of reservoirs would also be applicable to the Yazoo basin might be worthy of consideration.

By restraining the range of flood heights, which are now from 40 to 50 feet, and bringing them within a limit of 15 to 20, as is claimed to be possible by means of the outlets and reservoirs, the erosion of the banks, now impossible to prevent, would become manageable at moderate expense by revetments. Bars which obstruct navigation could be removed by dredging and excessive width curtailed by a change in position of levees so as gradually to correct the extreme variations of cross-section and secure greater uniformity of slope. These changes could be effected by moderate annual appropriations extended over many years and would not prove burdensome; they would be insignificant in comparison with the benefits secured.

It is not by the continuous levee or by any one system that the dangers that now menace New Orleans and the Valley of the lower Mississippi can be averted; but by a combination of several, directed by intelligence, after a careful study of localities and conditions. In this way, and in this way only, can the problems of the Mississippi be solved and the citizens of New Orleans, the inhabitants of the valley and the proprietors of plantations, be relieved for all future time from impending dangers in comparison with which the Galveston flood would sink into insignificance.

Mr. Seddon states that the Government has now expended about $40,000,000, on the Mississippi, the result of which has been to gain experience; in other words, to educate its engineers. An equal expenditure on proper plans would have built reservoirs in the St. Francis basin, secured a 20 foot navigation from the Gulf to Cairo and protected from floods perpetually. Is it not time that the costly experience gained by failures should be utilized ?